REMOVAL MERCURY FROM WASTEWATER BY ELECTROCOAGULATION USING IRON PLATE AS ELECTRODE

BY

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ABSTRACT

Electrocoagulation is the removal process that based on electricity which used electrolysis concept. This process can remove contaminant like mercury which cannot be removed through filtration. This technique is economic and environmental friendly for wastewater treatment. Research studied was performed using synthetic mercury to determine the efficiency of mercury removal using this process. The objective of this research is to investigate the efficiency of mercury removal using iron electrode using different parameters including flow rate, charge loading and distance between electrodes. Electrocoagulation OT-1 model was used to perform the experiment and conductivity meter was used to perform the analysis. After all the analysis were performed its shows significant result which is about 90.10% of mercury successfully removed from the synthetic mercury solution. The highest flow rate 160 L/h and longest distance between electrodes 5cm contributed to the result of 90.10% removal of mercury from synthetic mercury solution. The highest charge loading also play importance role on removal of mercury.

ABSTRAK

Electrocoagulation adalah proses penyingkiran yang berdasarkan elektrik yang menggunakan konsep elektrolisis. Proses ini boleh mengeluarkan bahan cemar seperti raksa yang tidak boleh dikeluarkan melalui penapisan. Teknik ini adalah ekonomi dan mesra alam untuk rawatan air sisa. Penyelidikan telah dilakukan menggunakan raksa sintetik untuk menentukan kecekapan penyingkiran merkuri menggunakan proses ini. Objektif kajian ini adalah untuk menyiasat kecekapan penyingkiran merkuri menggunakan elektrod besi menggunakan parameter kadar aliran, muatan cas dan jarak antara elektrod. Model Electrocoagulation OT-1 telah digunakan untuk melaksanakan eksperimen dan meter kekonduksian telah digunakan untuk melaksanakan analisis. Selepas semua analisis telah dijalankan menunjukkan hasil penting yang kira-kira 90, 10% merkuri berjaya dikeluarkan dari sintetik merkuri. Aliran tertinggi kadar 160 L / h dan jarak terpanjang antara elektrod 5cm menyumbang kepada keputusan 90.10% merkuri Berjaya dikeluarkan dari sintetik merkuri. Pengaliran caj tertinggi juga memainkan peranan yang penting penyingkiran merkuri.

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LIST OF SYMBOLS/ABBREVIATION

SYMBOL	DESCRIPTION
Hg	Mercury
$HgCl_2$	Mercury Chloride
NaCl	Sodium Chloride
HCl	Hydrochloric Acid
H_2SO_4	Sulphuric Acid
ppm	Part per million
C_o	Initial Concentration
C	Final Concentration
A	Ampere
V	Voltage

CHAPTER 1

INTRODUCTION

1.1 Background of study

Every industry in the world whether it is chemical, agriculture, manufacturing or any things else will produce its own domestic waste which can contribute to the water pollution. Water is one of the essential elements that very important for human being. One of the dangerous elements that may contain water pollution is heavy metal. Usually heavy metal is one of the sources of inorganic pollutants that always found in the industrial that mostly produced through waste water. Heavy metal can include elements lighter than carbon and can exclude some of the heaviest metals. Heavy metals occur naturally in the ecosystem with large variations in concentration. In organic pollutants and its particular heavy metals create a serious threat for the environment. These heavy metals can cause serious long term diseased such as teratogenic and carcinogenic. *(*Hyman*, et. al, 2004).*

One of the dangerous heavy metals is mercury. Mercury is mutagenic, carcinogenic, teratogenic and can promote tyrosinemia. Impairment of pulmonary and kidney function, chest pain and dyspnousea can be caused by high concentration of mercury. *(*Fu-shenzhang*, et. al, 2004).* The manufactures that produce heavy metal as their waste are clinical thermometer, paints that contain mercury sulphate, battery and accumulator that made up of mercury oxide. *(*Wesenbececk, *et. al, 2006).* The most famous example of acute mercury contamination occurred in fishing villages along the shore of Minamata Bay, Japan. Chisso, a chemical company located near the bay, used mercury sulphate and mercury chloride as catalysts in the production of acetaldehyde and vinyl chloride. Wastewater from the plant was discharged into Minamata Bay and contained both inorganic mercury and methyl mercury. The methyl mercury originated mainly as a side product of the acetaldehyde production process. Methyl mercury accumulated in the fish and shellfish in the bay and in local people who ate the fish and shellfish. The result was a form of mercury poisoning that is now known as Minamata disease. *(*Weinberg*, et. al, 2010).*

1.1.1 Industrial aspects

In recent years, there has been a growing need to eliminate hazardous pollutants from water. It is because many industries involved mercury on their product. Mercury is used as a component in many consumer products, like thermometers, batteries, electronic devices and many automotive parts, and can escape as a pollutant when these products are manufactured, broken during use, or most importantly, handled and disposed of at the end of the product's useful life. It can also be used as an additive to cosmetics and antiseptics, often exposing consumers unknowingly and unnecessarily. Incinerators burning mercury wastes, including discarded products, can release significant quantities of mercury unless they are equipped with appropriate mercury capture devices. Likewise, the recycling of scrap metal (secondary smelting) can release mercury from auto parts like light switches, if proper care is not taken to remove the mercury before smelting and/or mercury capture devices are not installed on the smelter.

Because of the serious effect of mercury, regulation of mercury pollution has finally begun to phase in among the largest emitters despite long delays and repeated attempts to weaken mercury regulations under the Clean Water Act. The Environmental Protection Agency finalized clean air safeguards to reduce toxic pollution, including mercury, from:

- cement plants in 2010
- power plants in 2011,
- gold mining in 2011, and
- industrial boilers in 2011,

New standards were proposed for the chlorine chemicals industry in 2011. Mercury emissions are slated to go down 80 percent by 2016 compared to 1990 levels, due to these US EPA regulations. *(*Natural Resources Defense Council, *http://www.nrdc.org/health/effects/mercury/sources.asp)*

This the pie chart of the industry that involved with the mercury waste.

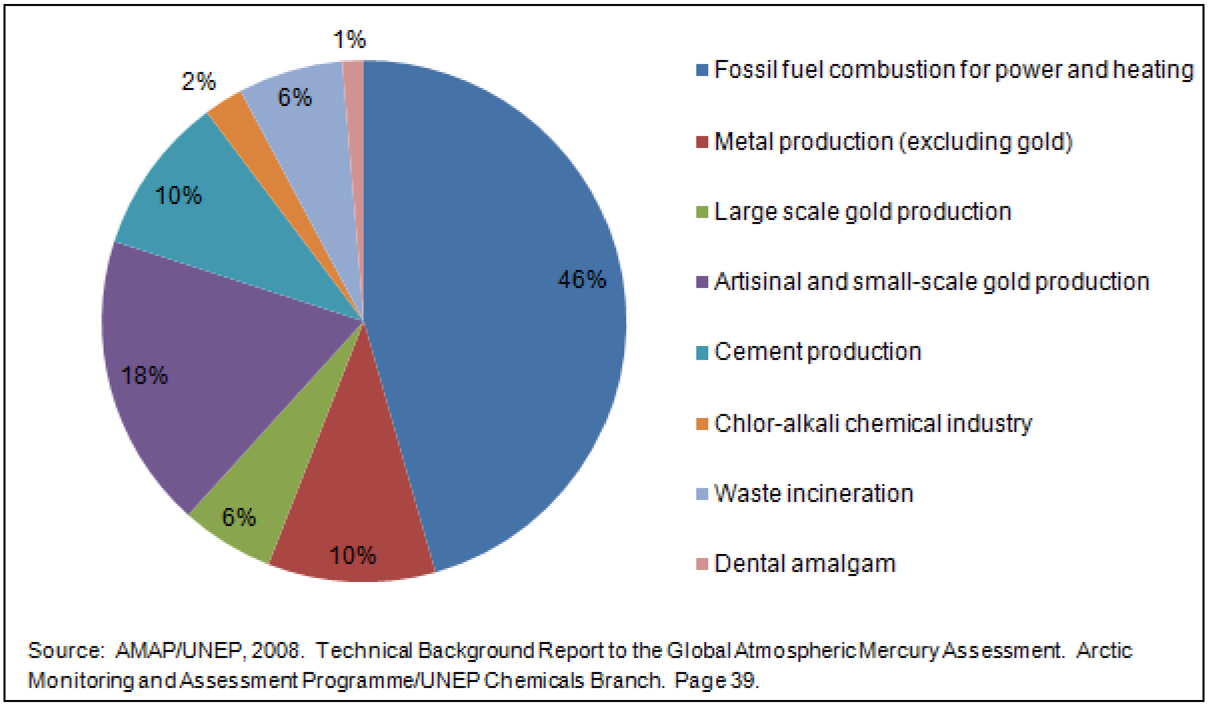

Figure 1.1: Industries that involved with mercury waste

Source: (AMAP/UNEP Chemicals Branch Page 39, 2008)

1.1.2 Electrocoagulation

Electrocoagulation is a complex process, with a multitude of mechanisms operating synergistically to remove pollutants from the water. A wide variety of opinions exist in the literature for both the key mechanisms and the best reactor configurations. Design variations include a fluidised-bed reactor employing pellets, bipolar electrodes, mesh electrodes, as well as simple plate electrodes. There is certainly no dominant ‘electrocoagulation reactor’ in use. Reported operating conditions and performance mirror the wide variation in design, with reactors invariably being ‘tuned’ to best suit a specific application. These empirical approaches invariably prove the viability of the technology, but singularly fails to fully capitalise on its potential. This is due to a lack of fundamental understanding of the system and hence the inability to accurately predict performance.

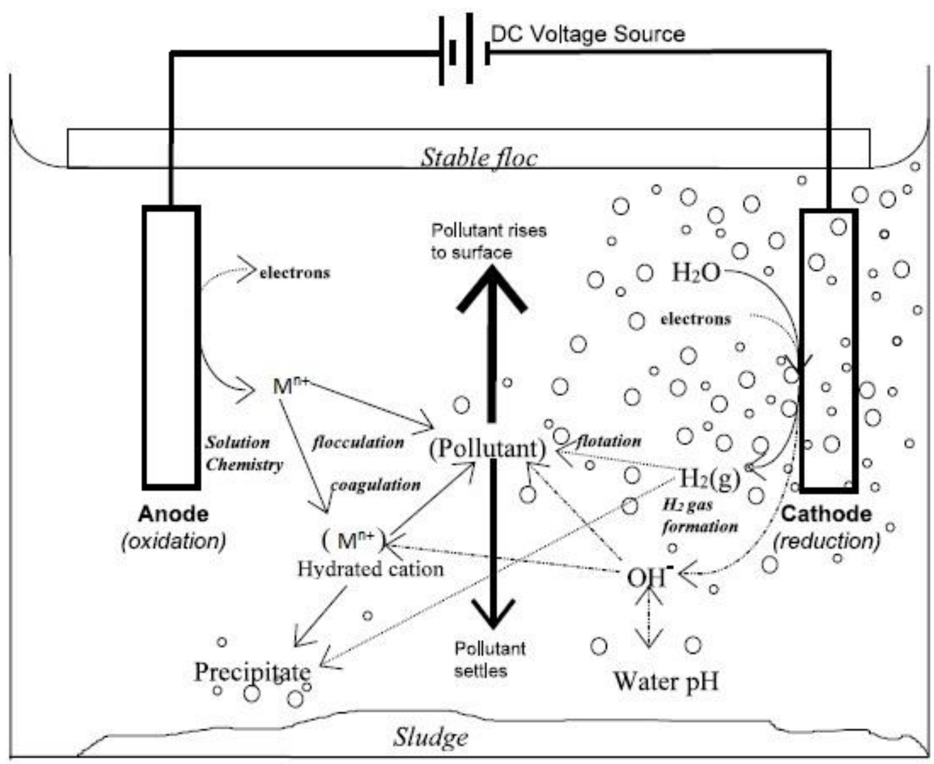

Figure 1.2 Interaction occurring within an electrocoagulation reactor

*Sources: (*Holt, *et. al, 2002)*

Figure 1.2 shows the interdependent nature of the electrocoagulation process. A sacrificial metal anode is used to dose polluted water with a coagulating agent. Simultaneously, electrolytic gases (mainly hydrogen at the cathode) are generated. It is possible to identify three separate categories of mechanistic process which are electrochemistry, coagulation, and hydrodynamics. These are the basis form of electrocoagulation process. The fact that these processes are difficult to investigate separately in an operational reactor goes some way towards explaining the lack of a detailed technical literature on electrocoagulation.

1.2 Problem Statement

Mercury is the one of contaminant in petrochemical wastewater. In petrochemical sector and industries, the production of mercury is very large every year. Mercury is heavy metal compound, so it is very dangerous to the human and our ecosystem. The production of mercury not only dangerous to the human and ecosystem but it also gives more problems to our equipment. Coagulation of Petrochemical waste is an important process in water treatment that helps to produce clear, finished water which is aesthetically acceptable to the consumer. Much of the suspended matter in water is colloidal (1 mm to 1 m) and negatively charged. Because of their large surface area and electrical charge, colloidal particles settle very slowly. Iron salts are used to neutralize these surface charges and to cause the colloids to combine and become large enough so that they will readily settle. But the conventional method which is chemical coagulation used to reducing the effects caused by the presence of mercury will increase the amount of sludge production. Other problems are permanent water hardness, water salts like sodium, annual high operation costs, sediment formation on membrane, which require an effluent post treatment and disposal of residual sludge. Before this, the scientist show that mercury cannot be degraded either biologically or chemically, and besides, it can be converted into more toxic compounds in the environment *(*Wang *et. al, 2004).* Therefore to overcome this problem, new alternative method like electrocoagulation may help to improve removal of mercury from petrochemical waste water.

1.3 Objective

The objective of this undergraduate research project is to remove mercury from the synthetic wastewater by electrocoagulation using iron as electrode and to investigate the efficiency of the electrocoagulation process in removal of mercury from wastewater by manipulating a few parameters..

1.4 Scope of study

The scope of study is to investigate the effect of parameter on mercury removal. Therefore, the scopes of study are:

i. Study the effect of charge loading efficiency on removal of mercury ion.
ii. Study the effect of flow rate efficiency on removal of mercury ion.
iii. Study the effect of distance between electrodes efficiency on removal of mercury ion.

1.5 Significant of study

Many problems are arises from chemical coagulant method such as permanent water hardness, water salts like sodium, annual high operation costs, sediment formation on membrane, which require an effluent post treatment and disposal of residual sludge while electrocoagulation utilizes methods that precipitate out large quantities of contaminants in one operation; the technology is the distinct economic and environmental choice for industrial, commercial and municipal waste treatment.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview of Mercury

Mercury is a natural element whose chemical symbol is Hg. This abbreviation comes from the Greek word hydrargyrum, which means liquid silver. In its pure form, mercury is a silvery-white metal that is liquid at standard temperature and pressure. In different contexts, pure mercury is often called quicksilver, metallic mercury, or liquid mercury. Most commonly, however, pure mercury is called elemental mercury. *(www.ipen .org)*

Because elemental mercury has high surface tension, it forms small, compact, spherical droplets when it is released into the environment. Although the droplets themselves are stable, the high vapor pressure of mercury compared with other metals causes the mercury to evaporate. In an indoor setting, mercury can quickly become an inhalation hazard. Outdoors, elemental mercury vaporizes and enters the atmosphere.

Elemental mercury can be produced for human use from an ore called cinnabar, which contains high concentrations of mercury sulfide. Elemental mercury can also be produced as a by-product from the mining and refining of metals such as copper, gold, lead, and zinc. Mercury can also be recovered by recycling operations and is sometimes removed from natural gas or other fossil fuels.

It has been estimated that approximately one-third of the mercury circulating in the global environment is naturally occurring and approximately two-thirds was originally released into the environment as a result of industrial and other human activities. The amount of mercury that is circulating in the world's atmosphere, soils, lakes, streams, and oceans has increased by the start of the industrial era. As a result, levels of mercury in our environment are dangerously high.

Several kinds of human activities release mercury into the environment. Mercury is present in fossil fuels, metal ores, and other minerals. When coal is burned, much of its mercury content enters the environment. Mining and refining metal ores and the manufacture of cement also release mercury into the environment.

Table 2.1: Properties of mercury

Some Properties of Elemental Mercury	
Property	**Value**
Atomic Weight	200.59
Atomic Number	80
Melting Point	-38.87°C
Boiling Point	356.58°C
Vapor Pressure at 25°C	2×10^{-3} mm Hg
Solubility in Water at 25°C	20–30 μg/L
CAS Registry Number	7439-97-6
Mass	13.5336 gm/cc

2.1.1 Forms of Mercury

Most mercury in the atmosphere is in the gaseous state, but some is attached to particulate matter. Gaseous mercury is mostly elemental mercury, but a small percentage has been oxidized into mercury compounds such as mercury chloride and mercury oxide. Pure mercury vapor, also called gaseous elemental mercury (GEM), has very low water solubility and is very stable in the atmosphere, with an estimated residence time of between six months and two years. This stability enables elemental mercury to undergo long range transport and causes GEM concentrations to be fairly uniform in the atmosphere.

However, mercury is usually found in inorganic or organic forms. In the inorganic form, it usually exists in various physical states: liquid (HgO) or solid (salts of Hg^{2+}, Hg^{2+} ions or oxide). However, inorganic mercury can combine with organic compounds to give organometallics, and sometimes methyl mercury under the action of bacteria for instance. In this final form, mercury is much more toxic and labile compared to its free form. In general, mercury contamination is favored by its high volatility which can make its inhalation through air, its high reactivity readily allows mercury to combine with various other elements, leading to quite stable species, and that can accumulate in sea products.

Elemental mercury is initially released into the atmosphere, captured by precipitation and ultimately deposited in the sediments of lakes and oceans. This process leads to the second type of the transport and distribution of mercury. It involves the deposition of mercury in the sediments of lakes and oceans and its transformation to a methylated species by anaerobic bacteria. The amount of methyl-mercury produced by anaerobic bacteria may be decreased by demethylation reactions and volatilization of dimethylmercury.

2.1.2 Sources of Mercury

Mercury Mining

The largest use of mercury during the sixteenth to eighteenth centuries was for the production of silver and gold in Latin America, and this use released enormous quantities of mercury into the global environment. Most of this silver and gold was shipped back to Spain and Portugal, where it became a major contributor to rapid economic expansion in Western Europe.

The nineteenth century saw a large boom of mercury mining in North America for use by gold rush miners in California and then northern Canada and Alaska. This gold production was an important contributor to economic expansion in North America. Nineteenth-century gold booms also occurred in Australia and in other countries. Large quantities of mercury from the gold and silver mining of earlier centuries remain in the environment and continue to be a source of harm.

Operations that mine mercury ores and refine them into elemental mercury release a large amount of mercury vapors into the air and are thus also a direct and significant source of mercury pollution. One study found atmospheric mercury concentrations around an abandoned mercury mine in China to be several orders of magnitude higher than regional background sites. A study of human exposure to mercury from eating rice grown in a district near mercury mines and smelters found high exposure, even when compared with districts near zinc smelters and heavy coal-based industries. Researchers in California measured significant amounts of mercury leaching into a creek flowing past a long-abandoned mercury mine site. This and preliminary results from other mine sites indicate that inoperative mercury mines are major sources of mercury pollution to water bodies, and they also, in turn, remain continuing sources of atmospheric mercury emissions as well.

Producing Elemental Mercury as a By-Product in Nonferrous Metals Refining

Elemental mercury is also sometimes produced as a by-product when various metal ores are refined. Mercury is found in trace quantities in most nonferrous metal ores such as zinc, copper, lead, gold, silver, and others. Until recently, the mercury content of these ores would be released into the environment as part of the waste streams generated during mining and refining. In recent years, however, some refiners have started to recover mercury from their wastes and produce elemental mercury for sale on domestic or international markets.

Elemental Mercury from Natural Gas

Natural gas contains trace quantities of mercury that is released into the environment when the gas is burned. In some areas including countries bordering the North Sea, Algeria, Croatia, and others the mercury concentrations in the gas are particularly high, and processors in these areas often remove mercury from their gas. It is estimated that 20–30 metric tons of mercury are recovered yearly from natural gas wastes in the European Union. Producers of liquid natural gas (LNG) remove mercury from natural gas before cooling it. Otherwise, the mercury present in the gas will damage the aluminum heat exchangers used in natural gas liquefaction plants. This typically requires reducing the mercury content of the natural gas to below 0.01 micro-grams of mercury per normal cubic meter of natural gas.

Mercury Recycling and Recovery

Most of the elemental mercury that is recovered by recycling comes from industrial processes that use mercury or mercury compounds. In some cases, the mercury that is recovered is reused by the industry. In some cases, it goes onto the market. And in some cases, agreements have been reached to remove the recovered mercury from the market and place it in permanent storage. The largest source of recycled or recovered mercury is the chlor-alkali industry. This industry produces chlorine gas and alkali (sodium hydroxide) by a process that applies electrolysis to saltwater. Some chlor-alkali plants use a mercury-cell process in which mercury is used as the electrolysis cathode. Mercury-cell chlor-alkali plants consume large quantities of mercury and are very polluting. Fortunately, the trend in recent years has been to phase out many of these mercury-cell plants in favor of other processes that do not use mercury. A single mercury-cell plant may contain hundreds of tons of elemental mercury for use in production and may have even more mercury in its warehouses to replenish lost mercury. When a mercury cell is decommissioned, much of this mercury can be recovered.

2.2 Health Effect

Mercury can give many bad effect to the human as well as environment. Mercury that usually exposed to human is methylmercury. It can cause many dangerous and harmful disease which related to mutation to human. Animal and ecosystem also can be affected by mercury.

2.2.1 Human Effect

Elemental (metallic) mercury and all of its compounds are toxic, exposure to excessive levels can permanently damage or fatally injure the brain and kidneys. Elemental mercury can also be absorbed through the skin and cause allergic reactions. Ingestion of inorganic mercury compounds can cause severe renal and gastrointestinal damage. Organic compounds of mercury such as methyl mercury are considered the most toxic forms of the element. Exposures to very small amounts of these compounds can result in devastating neurological damage and death. For fetuses, infants and children, the primary health effects of mercury are on neurological development. Even low levels of mercury exposure such as result from mother's consumption methylmercury in dietary sources can adversely affect the brain and nervous system. (Department of Health and Human services, National Institute of Health*)*.

Sources of exposure are widespread and include mercury vapors in ambient air, ingestion via drinking water, fish, vaccines, occupational exposures, home exposures including fluorescent light bulbs, thermostats, batteries, red tattoo dye, skin lightening creams, and over-the-counter products such as contact lens fluid and neosynephrine,